Damper Systems

Dave McGinnis

March 24, 2002

TEVATRON

1. Develop a digital delay card. This will be needed for the longitudinal and wideband transverse dampers
2. Develop a clean beam phase-locked 53 MHz clock system. This will be needed for all TEV damper systems.
3. Develop a “delay phased” fanout for the RF cavities which will be needed for the bunch by bunch damper and the feed-forward beam loading compensation.
4. Put direct RF feedback around all TEV cavities. This should be extremely simple because:
    a. The frequency swing is only 5 kHz during the ramp so there is no need for down-up conversion
    b. The RF voltage does not change that much so dynamic range should be less of an issue.
    c. There should be plenty of signal from cavity gap monitors so active components should be minimal or non-existent.
5. While the digital delay card is being developed, get a low phase noise longitudinal mode 0 damper system operational.
6. While the digital delay card is being developed, get a low phase noise longitudinal mode 1 damper system operational.
7. With a clean beam phase-locked 53 MHz clock system, build 1-Q transverse dampers. While these might not help that much during injection, they could allow for lower chromaticity up the ramp and during collisions. The tight specs on the noise performance should be easier to obtain with these narrow band systems.
8. Once the digital delay card is available, build a bunch-by-bunch longitudinal damper system. This system will need a 53 MHz notch filter to equalize the cavity phase response and a “delay phased” fan-out.
9. With the digital delay card, build wideband transverse dampers. These dampers will need a common mode rejection scheme and will probably be much lower gain than the 1-Q dampers because of noise tolerances. The wideband dampers and the 1-Q dampers will probably be used at the same time.
10. Build a feed-forward transient beam loading compensation. This system will need a “delay phased” fan-out. To avoid the complexity of trying to equalize the non-linearities of tube gain due to tube bias, it might be best to have a 465 card programmed to have different feed-forward gains.

Main Injector

1. Develop a clean beam phase-locked 53 MHz clock system.
2. Develop a “delay phased” fanout for the RF cavities, which will be needed for the feed-forward beam loading compensation.
3. Build a feed-forward transient beam loading compensation. This system will need a “delay phased” fanout. To avoid the complexity of trying to equalize the non-

linearities of tube gain due to tube bias, it might be best to have a 465 card programmed to have different feed-forward gains.

4. Build a Pbar transverse injection damper. This system will be very similar to a 1-Q damper system with the exception of a sample & hold placed downstream of the down-conversion.
5. Add a sample and hold to the present quadrupole damper to increase the signal/noise of the damper. The quadrupole damper helped proton coalescing during Run 1b.
6. Add Mode 1+ capability to direct RF feedback for each cavity system
7. Build 1-Q transverse dampers for NUMI operation. These dampers will have to share the same pickups, power amps, and kickers as the Pbar injection damper.
8. Build Mode 1 longitudinal damper for NUMI operation.
9. Build wideband transverse damper systems. These do not seem to be needed for the present proton intensities. These will also be difficult to build because of the slew in RF frequency.

Booster

1. Build longitudinal diagnostics for extracted beam. The should include the average bunch length at extraction, the average phase error at extraction, the rms value phase error at extraction, and a vector device that is the magnitude of each of the 42 coupled bunch modes.
2. The present tracking filters at 80 MHz filters should be replaced with tracking filters that work at down-converted frequencies (0-25 MHz). The tracking filters should include phase shifting at base-band.
3. Build 1-Q transverse dampers. These dampers are probably not needed when the chromaticity is large. However, they might permit the chromaticity to be lowered which could help the dynamic aperture (doubtful)
4. Wideband transverse dampers in the Booster are very hard to build because of the large frequency slow and large range of orbit motion and tune variations.

SUBJECT: TEV Bunch by Bunch Long. Damper

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$N_B = 36$ = number of bunches

Sample rate $= 53\,MHz \cdot \frac{N_b}{1113} = 1.7$ MS/sec

IF bandwith $= \frac{\text{Sample rate}}{2} = 0.86$ MHz

Total kicker bandwidth = 1.7 MHz

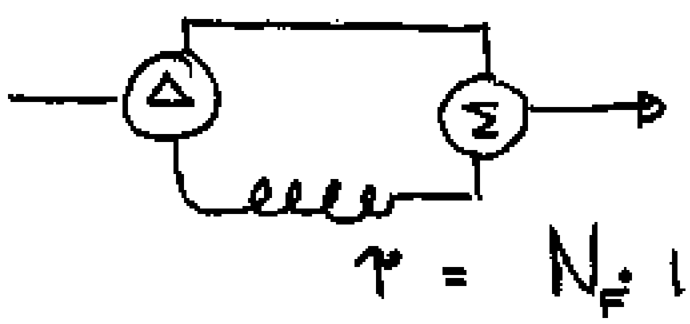
Cavity $Q \approx 5000$

Cavity Bandwidth $= \frac{53\,MHz}{Q} = 10.6$ kHz

Cavity Phase @ $53\,MHz \pm .047\,MHz = \mp 84°$

$\therefore$ Need to Equalize Cavity Phase!

Use a 53 MHz notch filter



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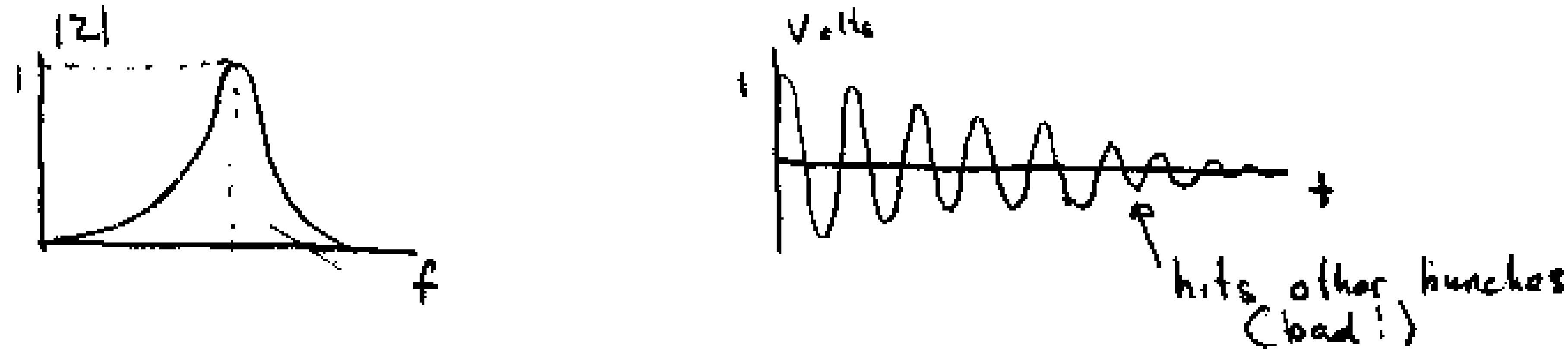
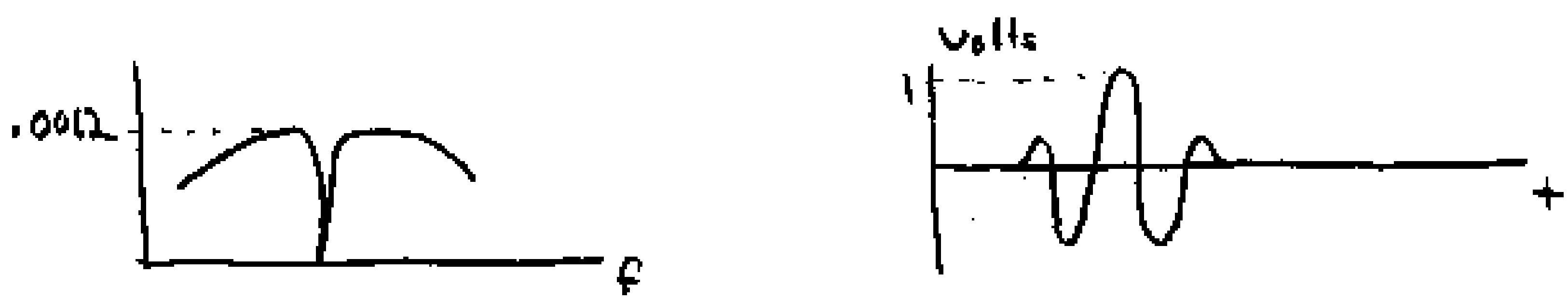
Cavity Response with out filter



Cavity Response with filter $N_F = 1$

Cavity Response with filter $N_F = 2$



∴ Even though Narrowband transfer impedance in freq domain drops dramatically with filter, bunch by bunch Gain does not drop.

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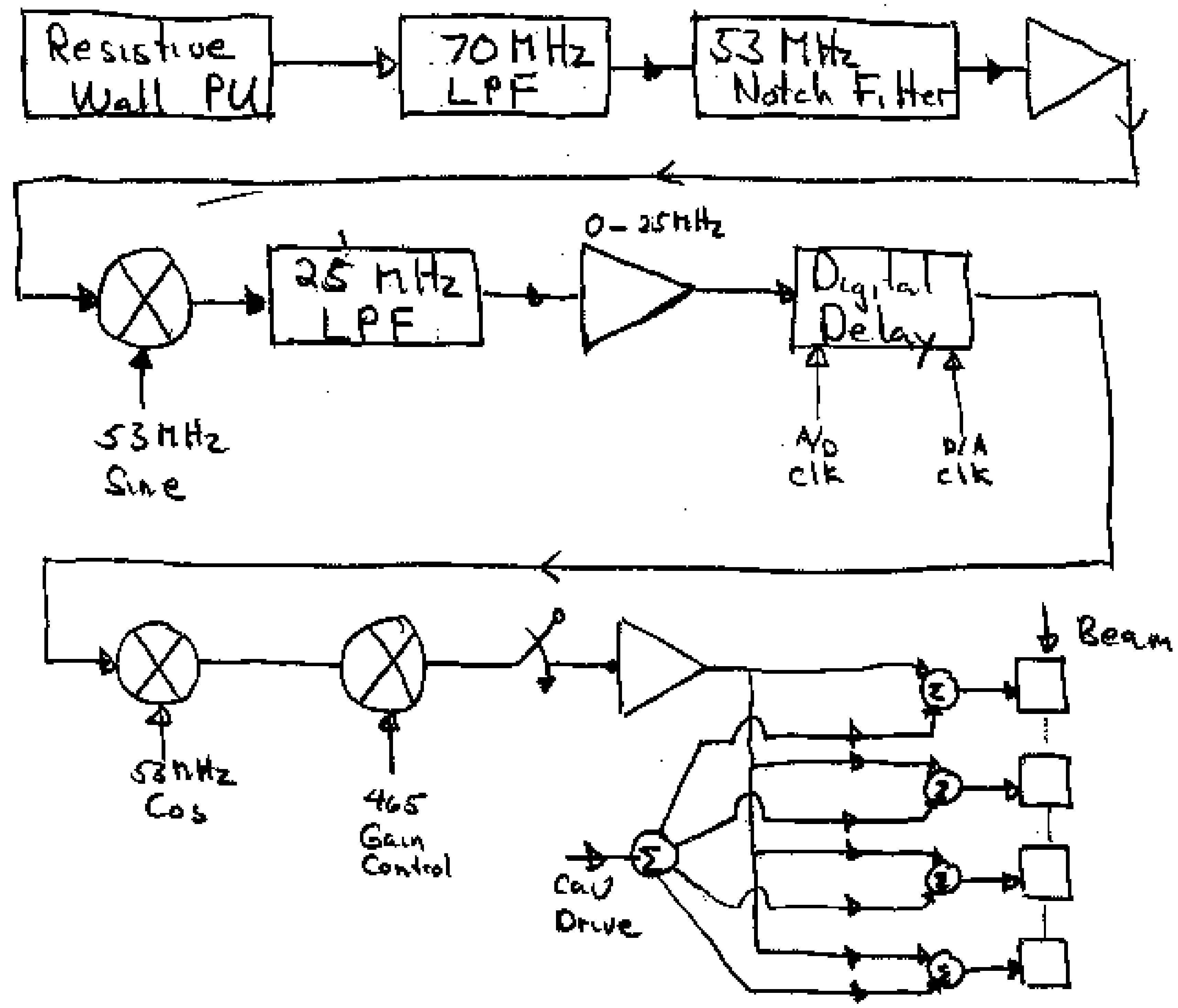
System Diagram



1) Need a Clock signals that are phase locked to beam

2) Damper Fanout is different than cavity drive fan out.

SUBJECT: TEV Digital Delay Card

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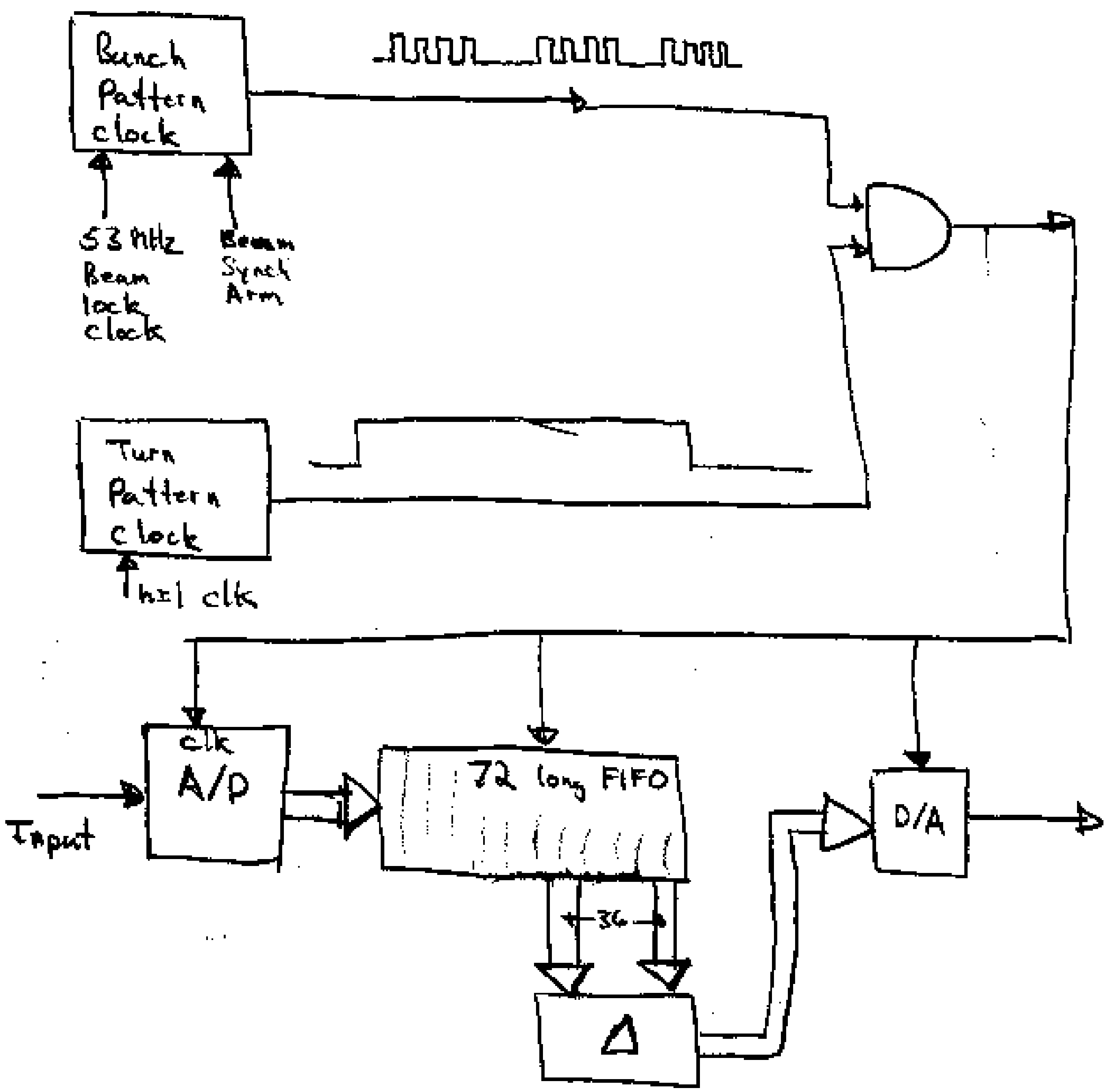

1) For betatron signal, Turn pattern clock is high all the time

2) For long damper Turn pattern clock is on only every $\approx \frac{f_{rev}}{6 f_{synch}}$ turns.

3) Need to figure out "details" of slightly less than 1 turn Delay.

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SUBJECT: I-Q Damper

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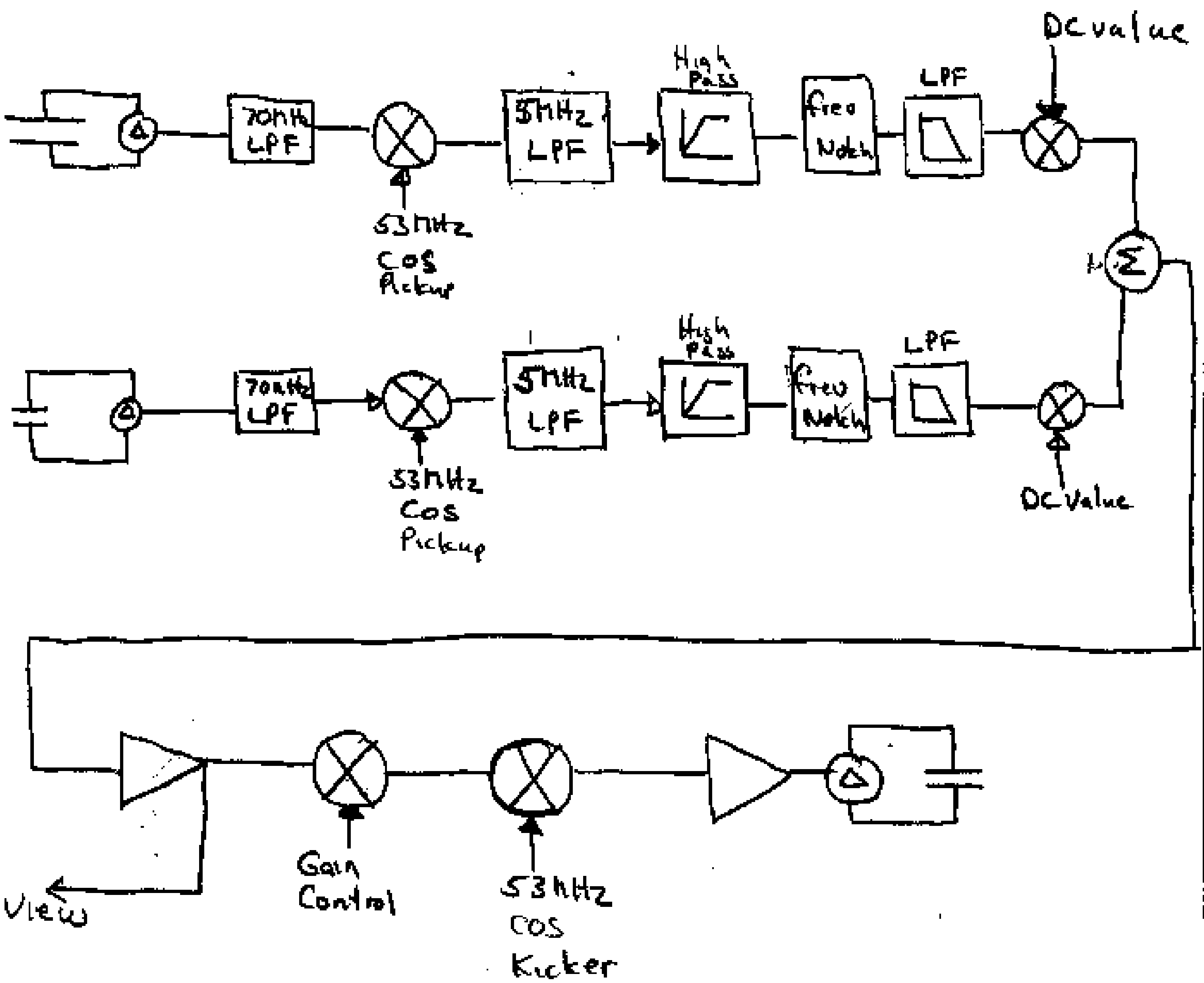
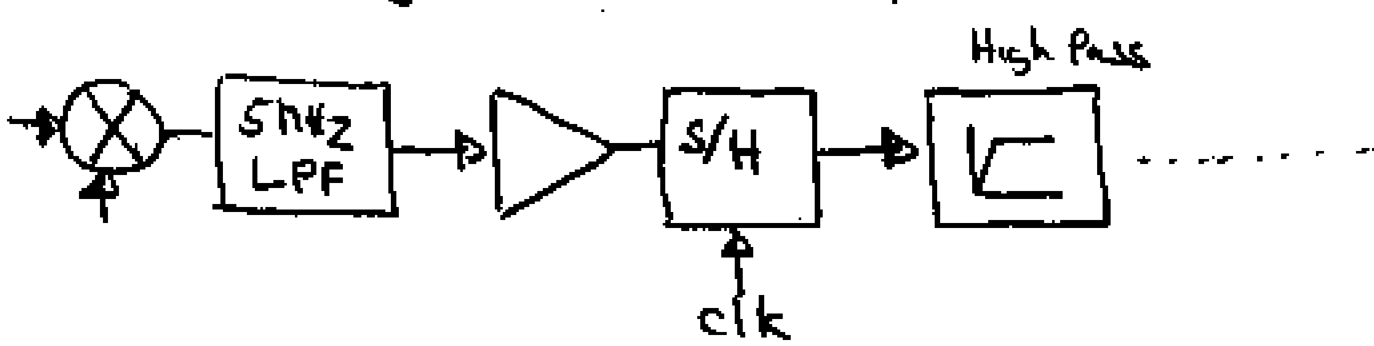


1) Pbar Injection Damper would have



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SUBJECT: 53 MHz Feed forward

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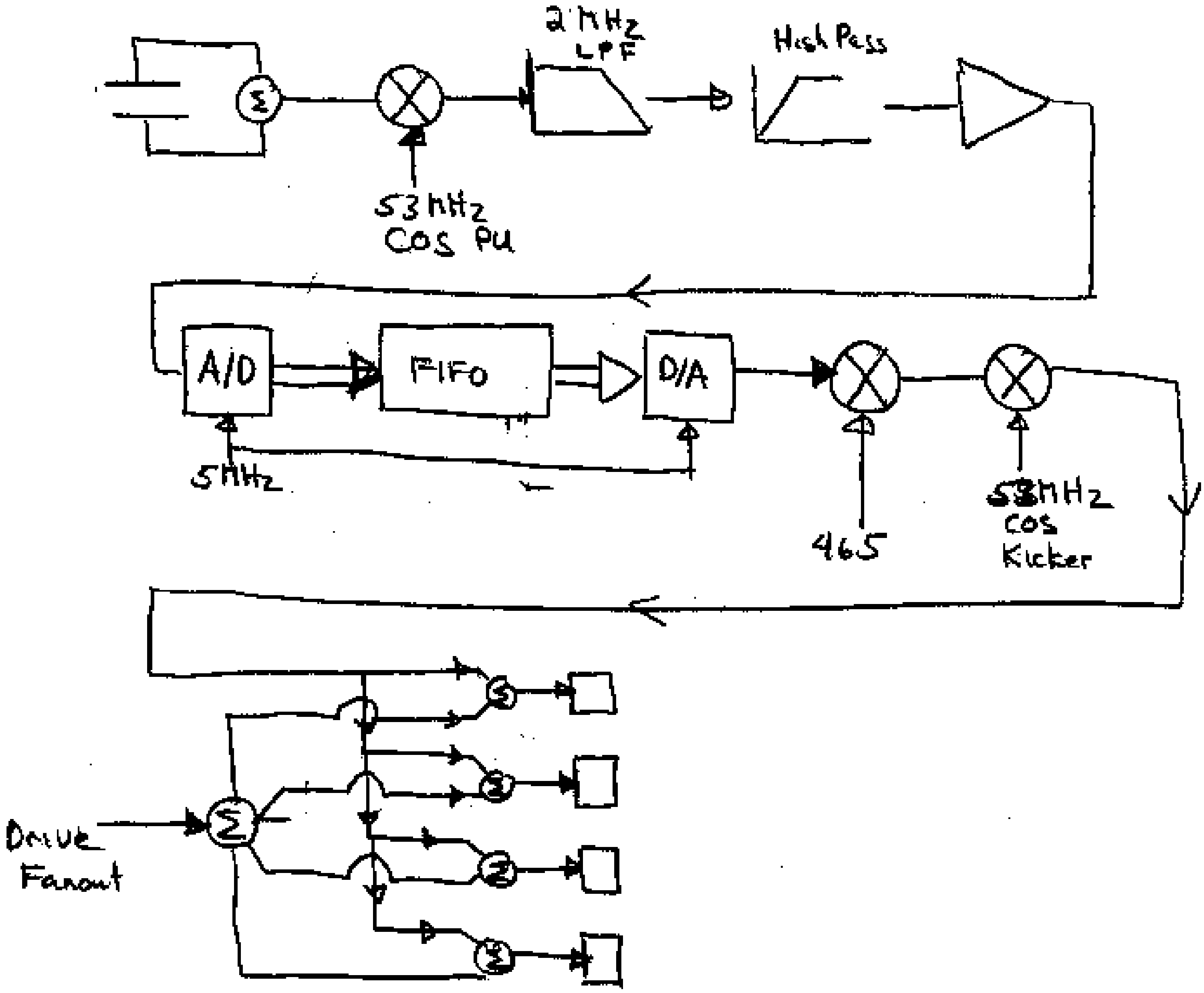

1) Use 465 to specifically tune up feed forward gain for different times in cycle when tube bias is different

2) Must have different fanout than Drive fanout

TEV must feed into $\bar{p}$ cavities as well

or over compensate proton cavities

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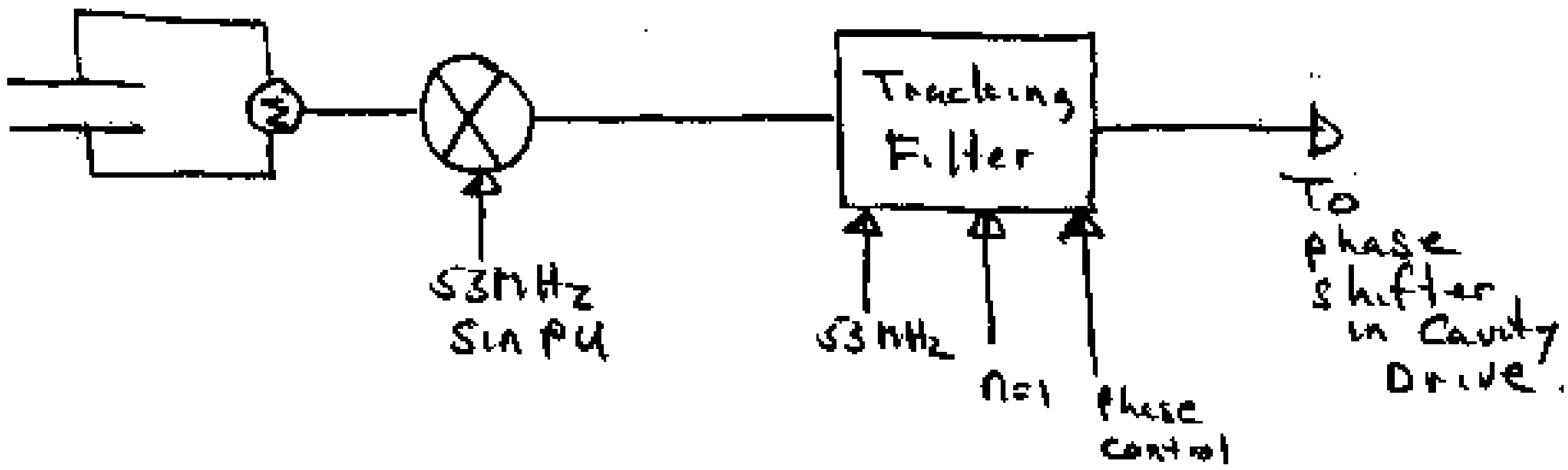
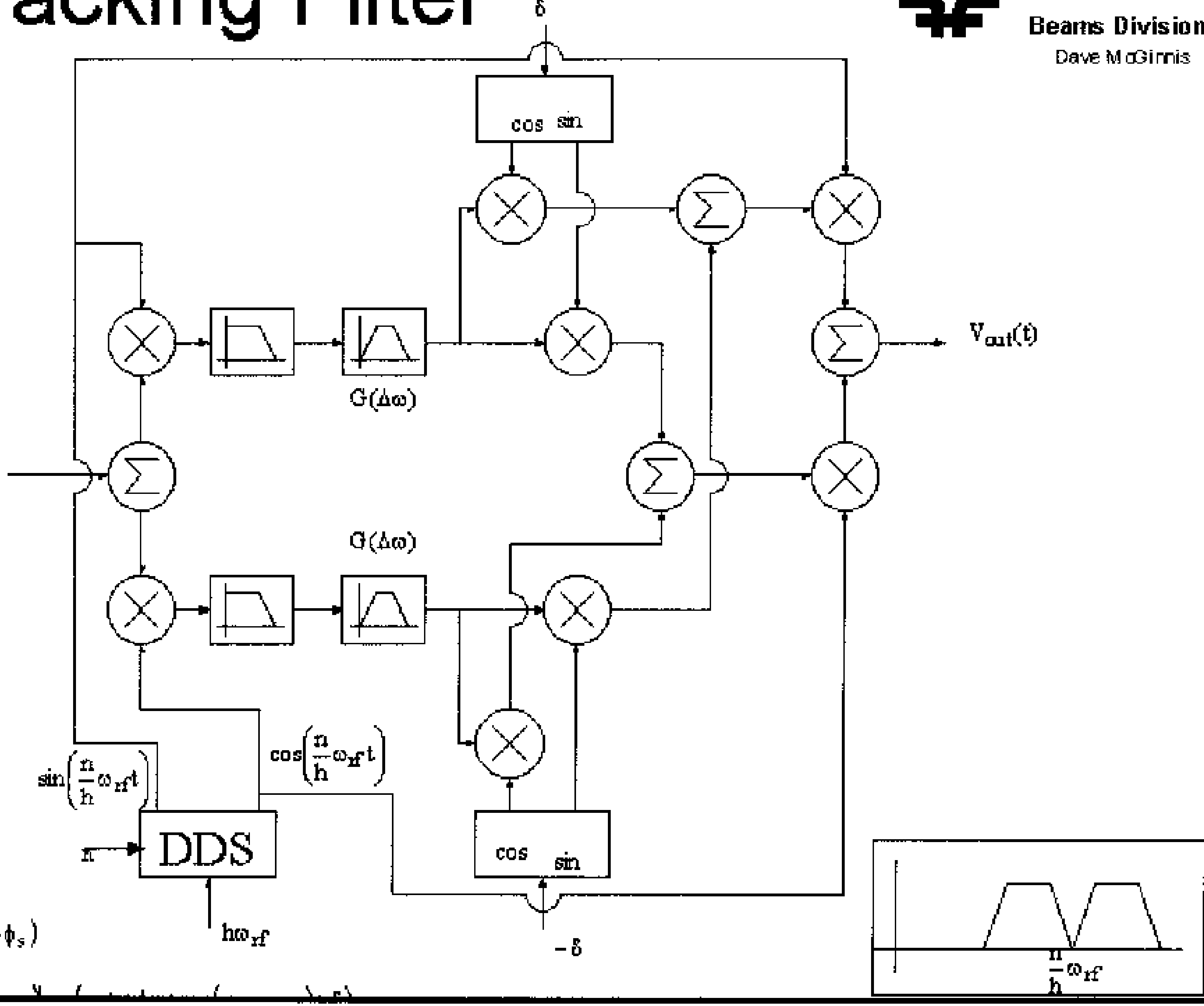
SUBJECT: Mode 1 Long. Damper

NAME	
DATE	REVISION DATE



Mode N Tracking Filter

Fermilab
Beams Division
Dave McGinnis



$V_{in}(t) = V_o \cos(\omega_s t + \phi_s)$

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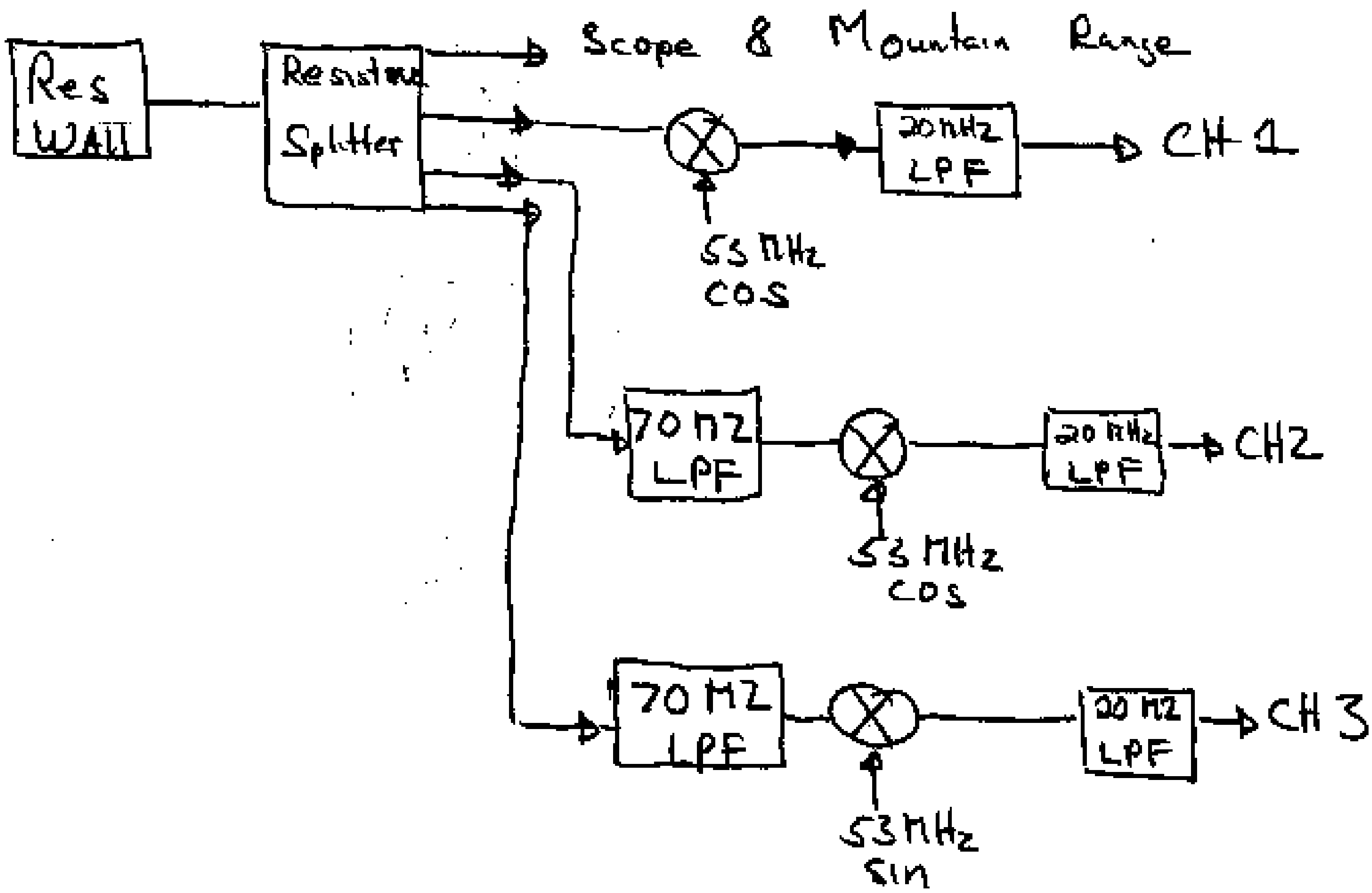
Booster Long. Diagnostics	DATE	REVISION DATE



$$\langle \text{Bunch Length} \rangle = \left[\frac{1}{N} \sum_i \frac{Ch2_i}{Ch1_i} \right] \frac{1}{52.812\ \text{MHz}}$$

$$\Phi_i = \tan^{-1}\left(\frac{Ch3_i}{Ch2_i}\right)$$

$$\langle \Phi \rangle = \frac{1}{N} \sum_i \phi_i$$

$$\Phi_{rms} = \sqrt{\frac{1}{N} \sum_i \left(\phi_i - \langle \phi \rangle\right)^2}$$

$$\Phi_m = \frac{1}{N} \left| \sum_i \phi_i e^{-j 2\pi m \frac{i}{N}} \right|$$